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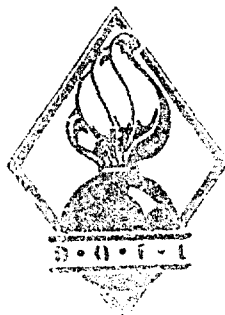
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TR-933

LIGHT-GAS GUN FOR PRODUCTION
OF SHOCK PRESSURE IN SOLIDS

H. R. Kollmeyer

15 AUGUST 1961



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TR-933

LIGHT-GAS GUN FOR PRODUCTION OF SHOCK PRESSURE IN SOLIDS

H. R. Kollmeyer

**FOR THE COMMANDER:
APPROVED BY**

Israel Rotkin
**Israel Rotkin
Chief, Laboratory 300**



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ABSTRACT

A 4-in. air gas gun has been modified to use light gases and is capable of accelerating 150-gm masses to 4000 fps as a routine operation. Photoelectric means are employed to measure the projectile velocity to ± 1 percent. The first application was to provide normal impacts of flat-faced projectiles as a method of producing a continuous range of shock pressures in solids. Special features are incorporated to facilitate experiments of this kind.

1. INTRODUCTION

Shock waves may be produced in solids by the impact of two flat-faced projectile plates (ref 1 and 2). Two light-gas guns have been constructed at DOFL to produce such impacts in order to study the effects of shock waves on the mechanical and electrical properties of insulating and conducting solids (ref 4, 5, and 6). This work is part of a program to study basic physical phenomena, the knowledge of which may be applied to the development of transducing devices for Ordnance Corps applications (ref 7).

The theory of the production of such shock waves, as discussed in the references, demonstrates that determination of the shock pressure depends on the determination of impact velocity. Therefore, the guns were designed with provisions for the accurate measurement of impact velocity, with the capability of producing normal impact, and for convenience of operation. One of the guns described in this report is a modified version of an air gun. It is capable of accelerating 200 gm to 1200 m/sec. An earlier modification is described in reference 3. The other gun (ref 8) is similar in principle. However, it operates to produce somewhat higher velocities (1525 m/sec), for considerably smaller masses (10 gm), with an eventual practical capability of accelerating these projectiles to about 8000 fps.

The gun described here is 96 ft long with a 4-in. inside diameter. The theory on which the design of this gun is based is described in ref 3. The tube is divided by the projectile into an evacuated section and a high-pressure section. The projectile, which carries the impacting plate, is held in place by a notched member that fails in tension at some predetermined pressure and releases the projectile. The final projectile velocity is a function of the ratio between the projectile mass and the firing pressure, which may be varied to obtain a continuous range of impact velocities.

2. DESCRIPTION OF GUN

2.1 Description of the Gun Tube

The gun tube, made at Watervliet Arsenal in 1951, was originally assembled as an air gun composed of 12 sections. These are 8 ft long with a 4-in. inside diameter and a 6-in. outside diameter. There are copper seals between the sections making the gun vacuum tight.

2.2 Breech Mechanism

The light-gas gun breech mechanism (fig. 1, 2, 3, and 4) is installed between the first and second sections of the original air-gun tube.* The strut shown in figure 3 holds the projectile by a threaded connector. An unintentional firing of the gun in its air-gun capacity while the strut is in place could do extensive damage to the air-gun tube and the new breech mechanism. Therefore a microswitch interlock is located in the breech cover to open the air-gun firing circuit unless the strut is removed and the breech cover is in place.

The breech cover shown in figure 4 is held by six high-strength bolts and sealed by an O ring on the inside upper edge. The strut is locked in position in the breech by the cover to prevent damage by excessive recoil of the strut when the projectile is released. The strut and projectile are assembled first and then placed in the breech cavity. The unit is moved forward until the projectile intercepts the O-ring seal and the front stop of the strut butts against the forward end of the strut slot.

2.3 High-Pressure System

Helium bottles are located outside the building. A system of electrically controlled valves is used to control the filling of the high-pressure section of the gun. The valves may be operated from either of two firing panels, one near the breech and one near the muzzle of the gun. Wiring diagrams of this system are shown in figures 5, 6, and 7.

2.4 Vacuum System

A Cenco Hypervac 100 pump with a free air capacity of 16 l/sec is used to evacuate the fore part of the gun. The system is connected to the gun by a T section at the muzzle; 3-in. copper pipe is used to connect the gun to the vacuum pump.

A double reverse-flow oil trap is placed between the gun and the pump to prevent fragments and dust caused by the impact, from being exhausted into the pump. The configuration of the trap and the air-flow patterns are shown in figure 8.

The oil trap is followed on the vacuum line by an electrically controlled, air-operated Stokes 3-in. gate valve. The valve operation is controlled from the firing panel and interlocked so that the gun cannot be fired with this valve open. This prevents damage to the cold trap, gauges or pump from the pressure surge associated with the firing.

*The gun may still be used in its original, low-velocity, high-mass, air-gun configuration by this arrangement.

Following the gate valve in the vacuum line is a cold trap and connections for various vacuum gauges. The pressure is reduced to less than 1μ of mercury in the entire evacuated section after about 10 min of pumping.

There is an interlock switch on the main firing panel (S_2 , fig. 5) to prevent the firing of the gun when the gate valve between the gun and the vacuum pump is open. This switch opens the firing circuit when the vacuum pump is connected to the gun through the open gate valve. A green light indicates that the firing circuit is locked out and the gate valve is open. When the gate-valve switch is in the closed position, the gate valve closes and the green light goes out. A red light indicates that the gun is ready to fire.

2.5 Catch Box and Safety

The catch box is designed to contain the explosions resulting from the impact of high-velocity projectiles. The box is constructed of hot-rolled 2-in. steel plates, welded together. A heavy hinged top plate is raised and lowered by an electric hoist. The front plate is connected to the muzzle of the gun by a removable sleeve.

An interlock system in series with the door to the catch box room (fig. 5) prevents inadvertent firing of the light-gas gun while the door is open. If the door is opened unintentionally, it will cause a microswitch to operate a relay (R_1) which transfers the firing circuit from S_2 to S_3 , in addition, the ready light on the control panel goes out. At the same time, the relay R_1 (fig. 5) switches the voltage from the firing circuit to the release circuit relay R_2 (Fig. 6). Closing of relay R_2 opens a valve, voiding the high-pressure section of the gun, thus releasing any gas pressure on the projectile.

The pressure section can also be voided if desired by pressing a special panic button on the main firing panel as well as on the remote firing panel.

3. PROJECTILE VELOCITY MEASUREMENT

The velocity of the projectile is determined by measuring the time interval between the interruption, by the projectile, of two light beams placed 1 ft apart (fig. 9 and 10). The sources for the light beams are a pair of projector exciter lamps. The lamps are mounted in identical lamp housings and the filament images are focused by lenses onto slits 0.010 in. wide. The slits are located close to the inside diameter of the gun tube behind intervening glass windows so that the gun tube may be vacuum tight. The windows are held in steel adapters fixed in the gun tube by threads and sealed by O rings. The 0.010-in. wide slit is cut into the closed end of the lens tube and is held in a position perpendicular

to the axis of the gun tube by the lamp housing. The interruptions of the light beams are detected by a pair of 931A photomultiplier tubes placed opposite the light sources. The adjustable light beams are positioned to fall 1/8 in. off center at the photocell side of the tube. The beam is inclined toward the muzzle end of the tube. Directing the beam toward the muzzle allows the projectile to interrupt the beam where it is narrowest, since it diverges after passing through the slit. This gives the maximum resolution of the optical system one part in 600.

The multiplier phototube circuit is shown in figure 11. Each tube has a separate power supply to prevent any cross coupling. The variable transformer (T_1) is adjusted to supply 1250 v to the cathode. The exciter lamps, marked CL on figure 11, are supplied with 8-v filtered dc to prevent 120-cps hum from modulating the light and producing an undesirable signal in the phototube output circuit. The lamp voltage is set by adjusting rheostat R4 with the lamps in the circuit so the voltage across both lamps is 8 v. The output is fed directly to cathode-follower probes which transmit the 4 v start and stop signals to the time interval meter. A high-pass filter prevents low-frequency signals generated by gun barrel vibration from triggering the interval meter.

The time interval meter has a resolution of $\pm 0.1 \mu\text{sec}$ and is accurate to one part in 10-million. The velocity measured with the combined optical-interval meter system has a resolution of ± 0.2 percent and an accuracy of ± 1 percent.

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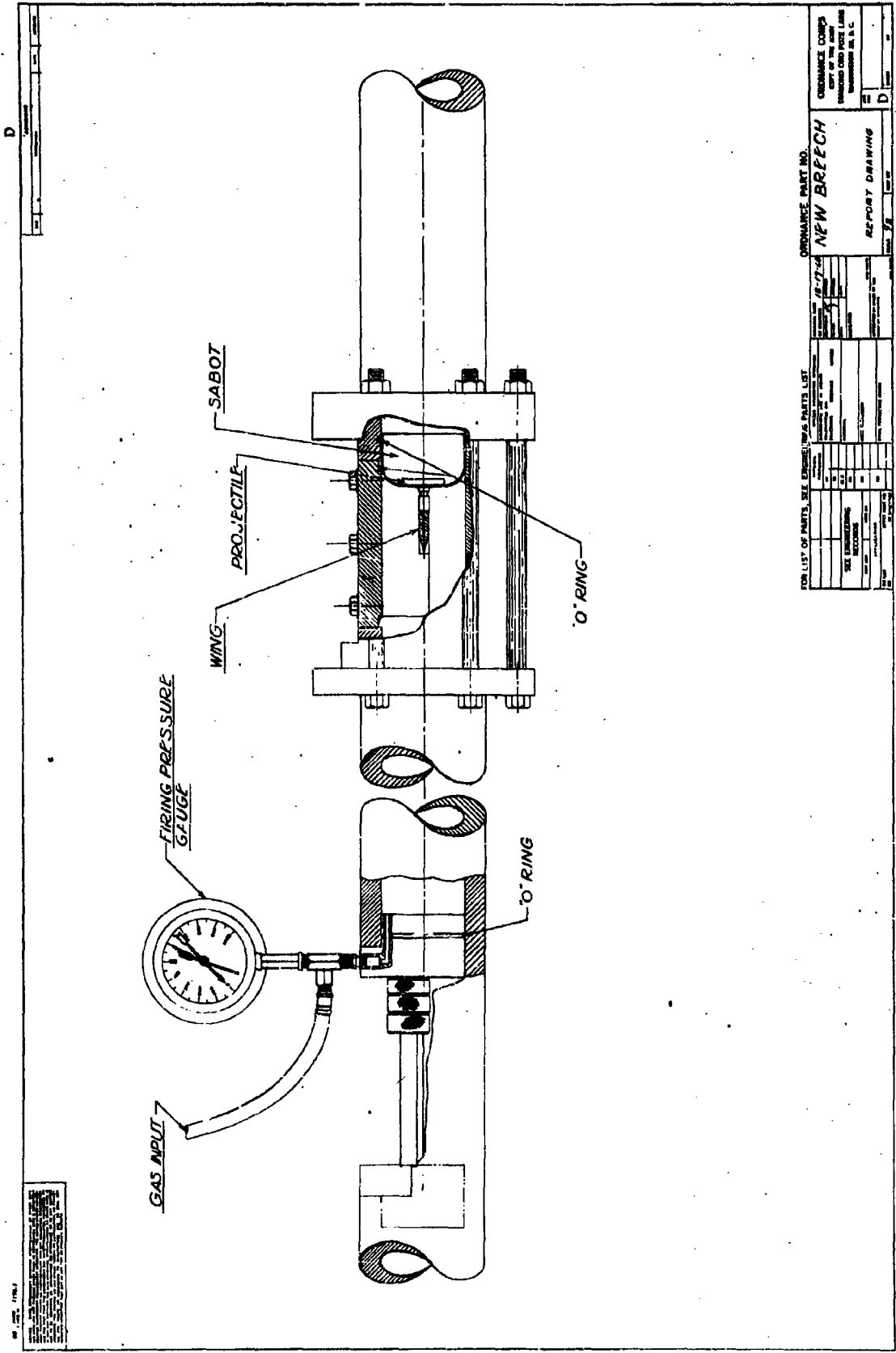
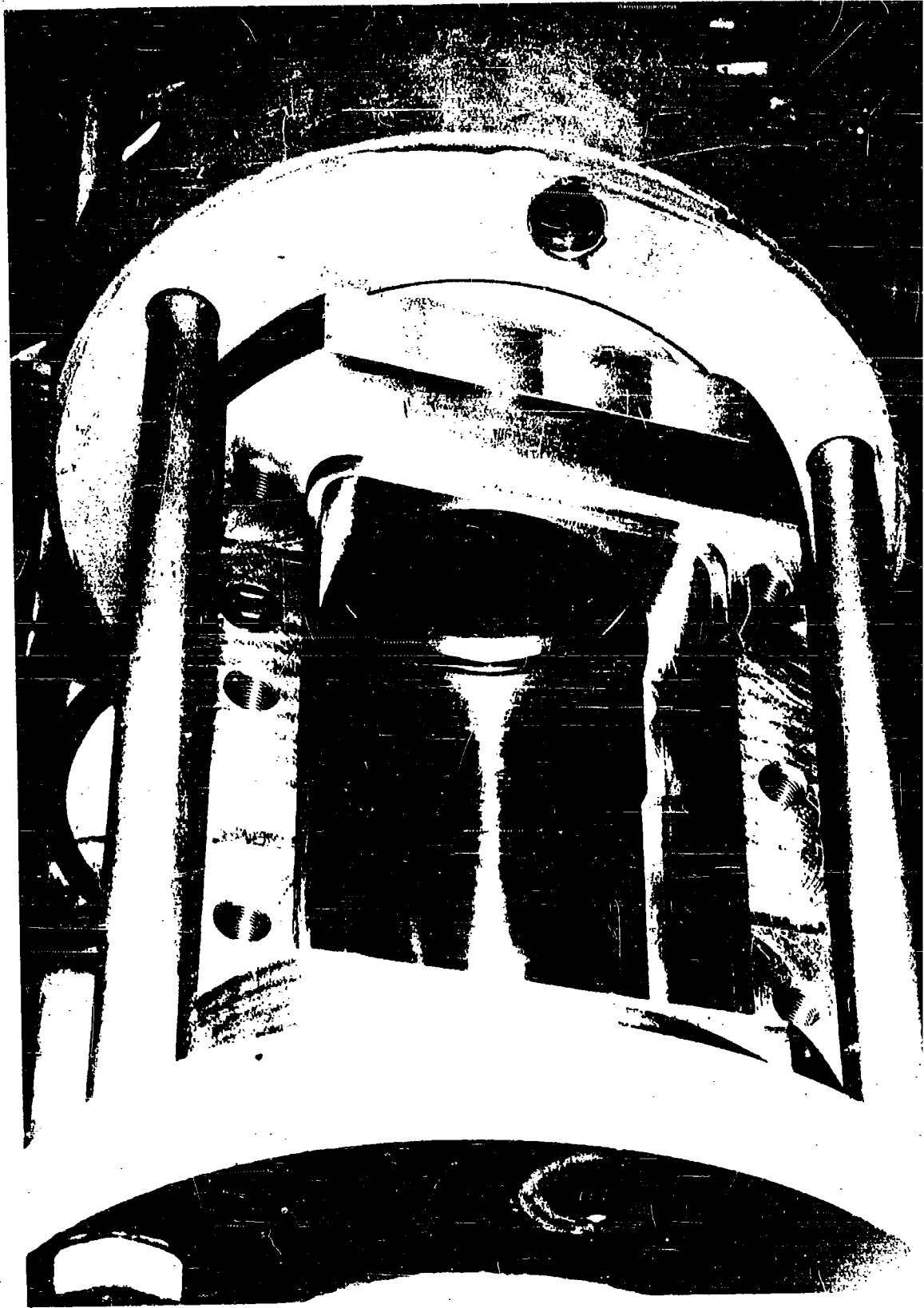


Figure 1. Breech mechanism.



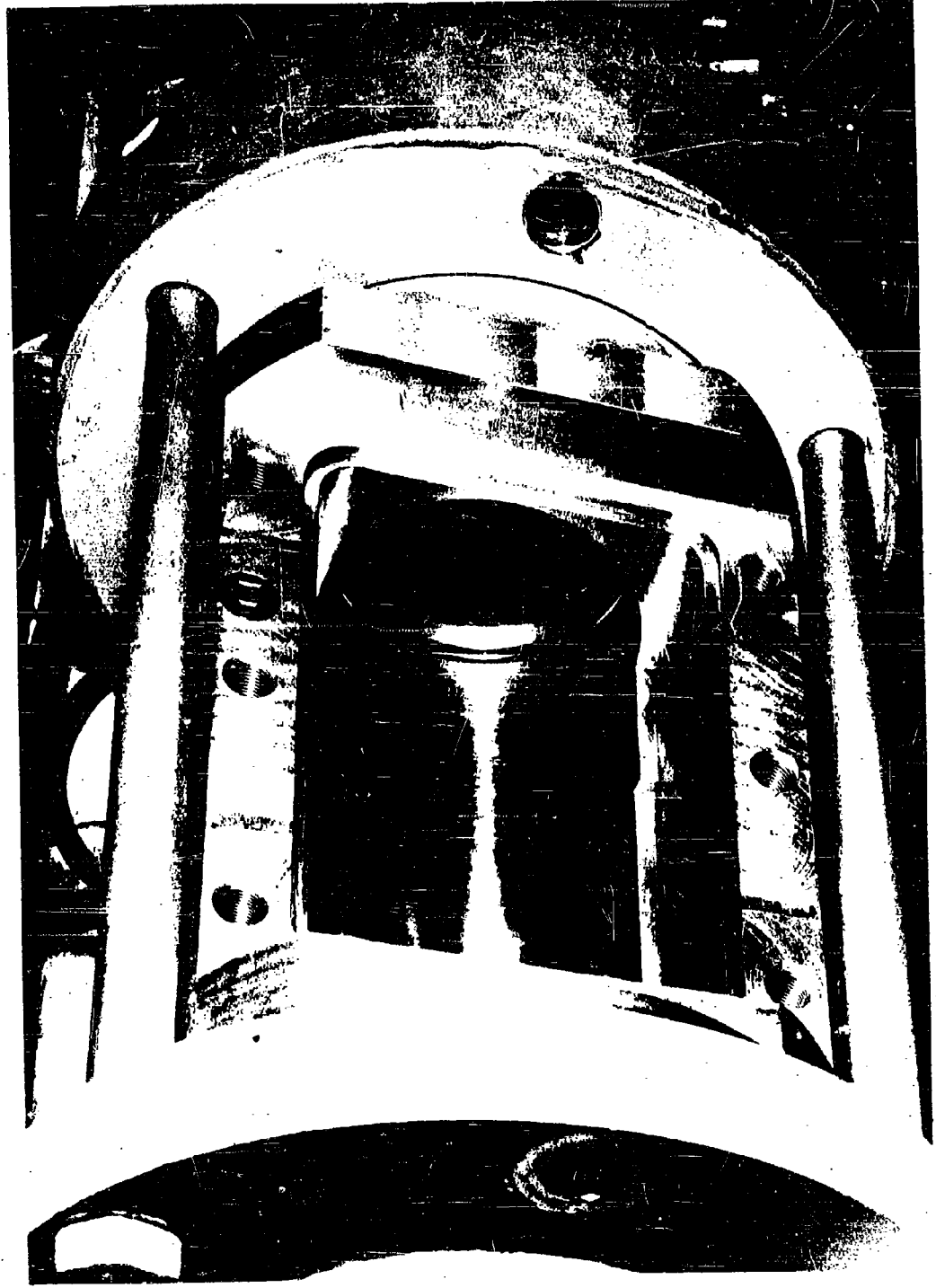


Figure 2. Open breech.

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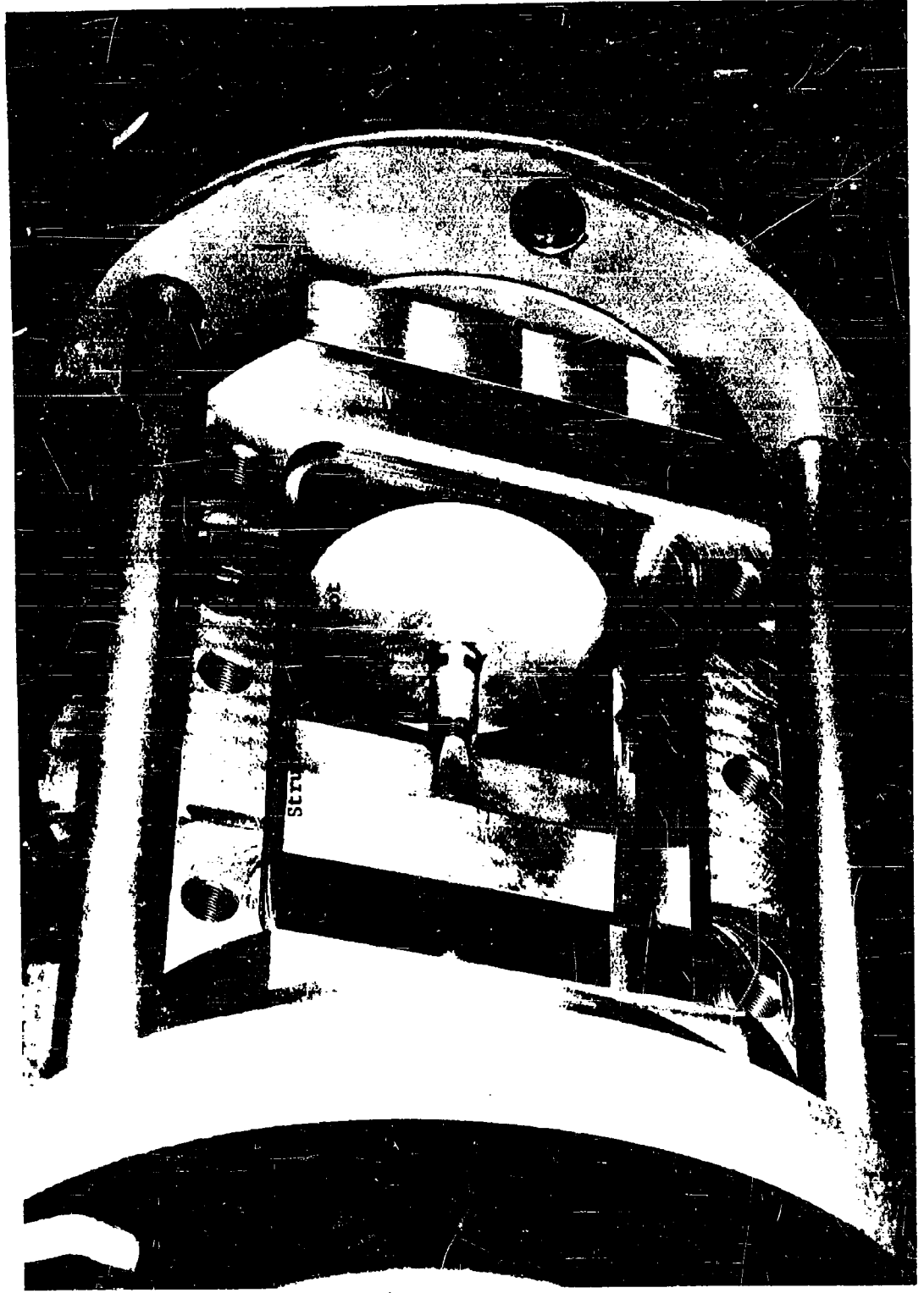
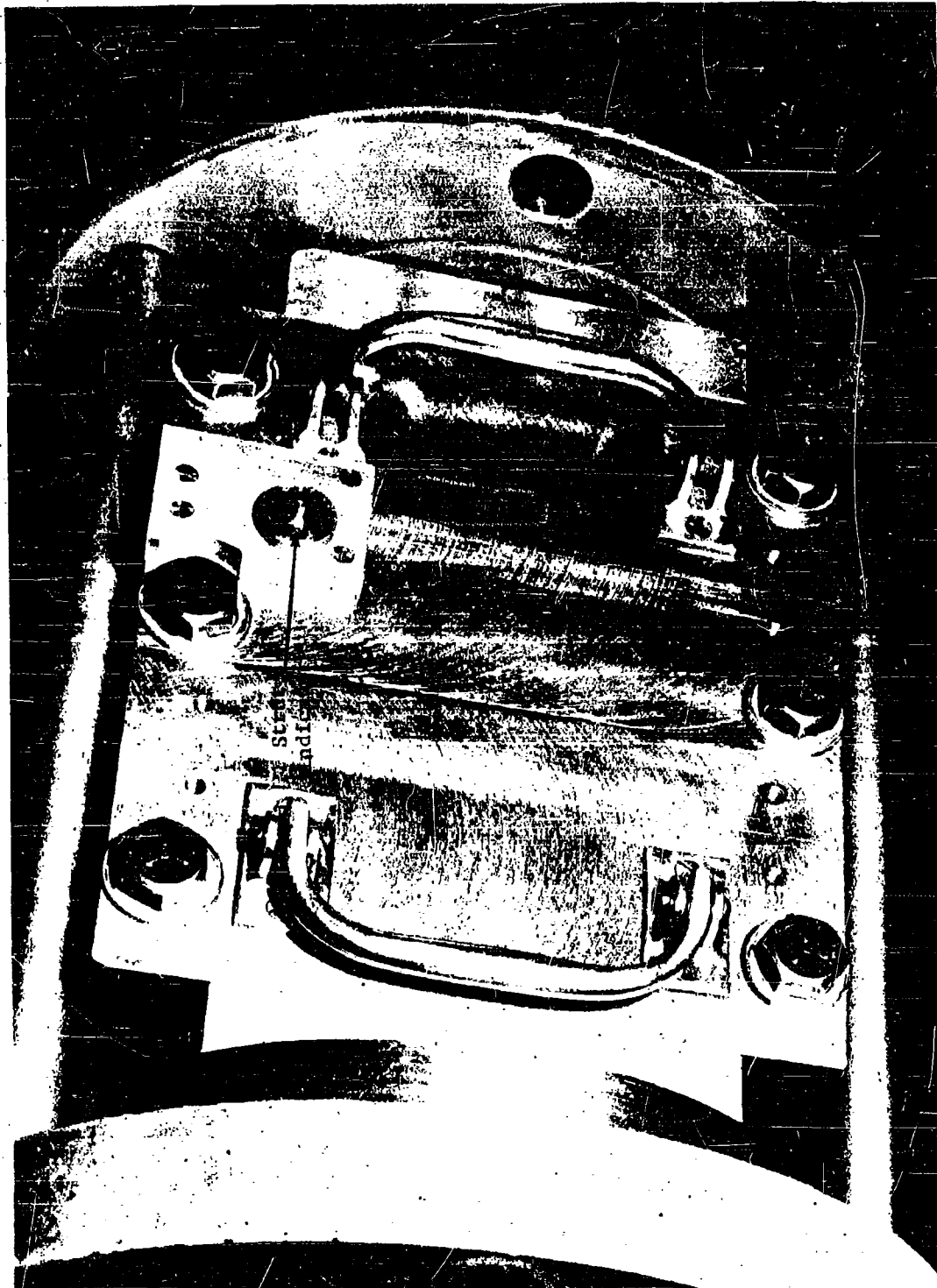


Figure 3. Open breech with sabot.



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Figure 4. Closed breech.

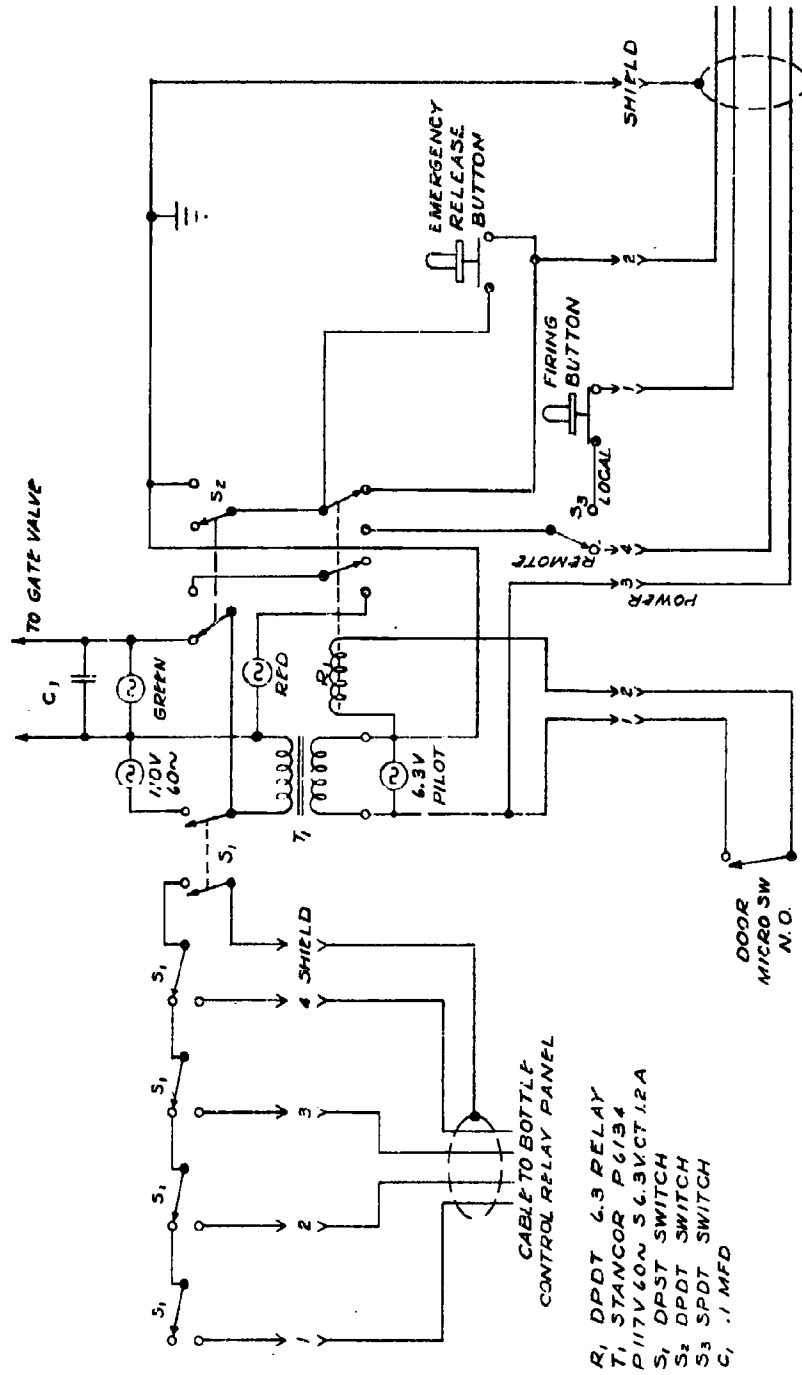


Figure 5. Main firing control circuit.

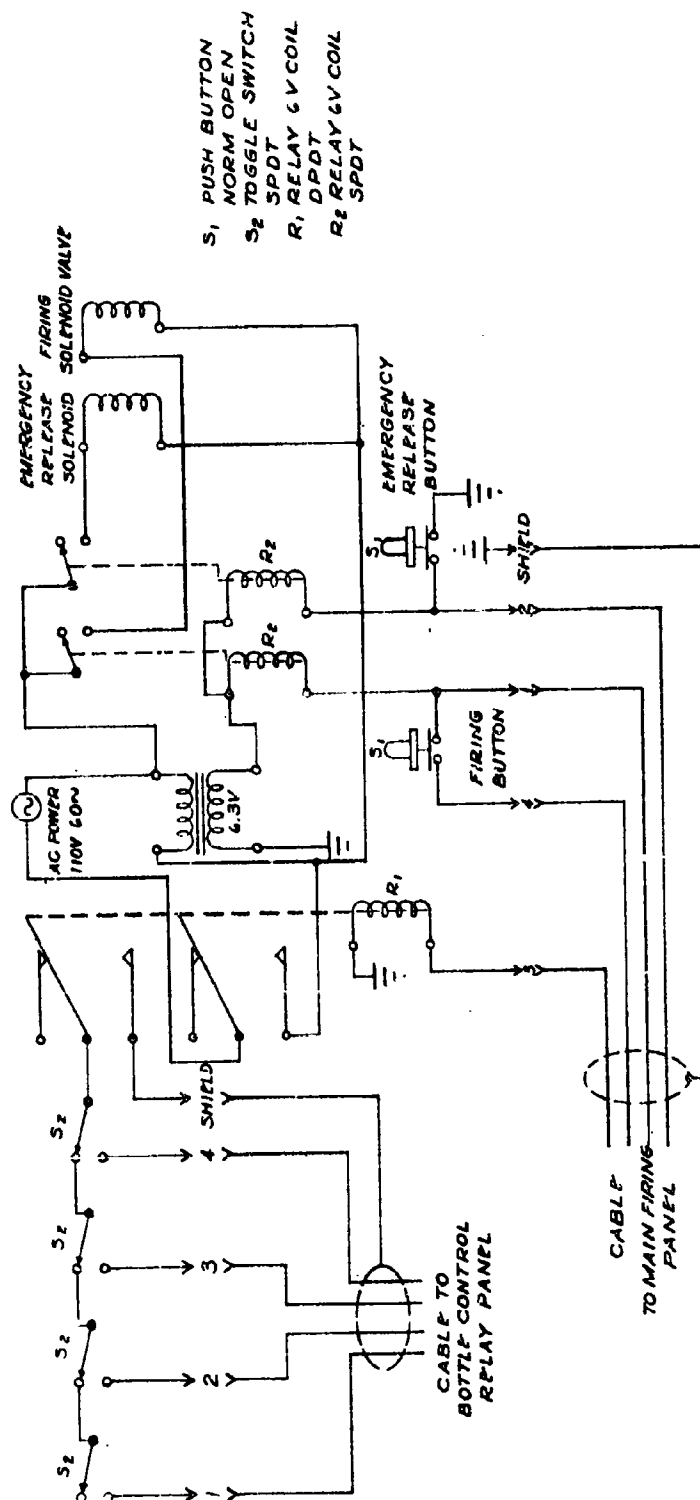


Figure 6. Remote firing control circuit.

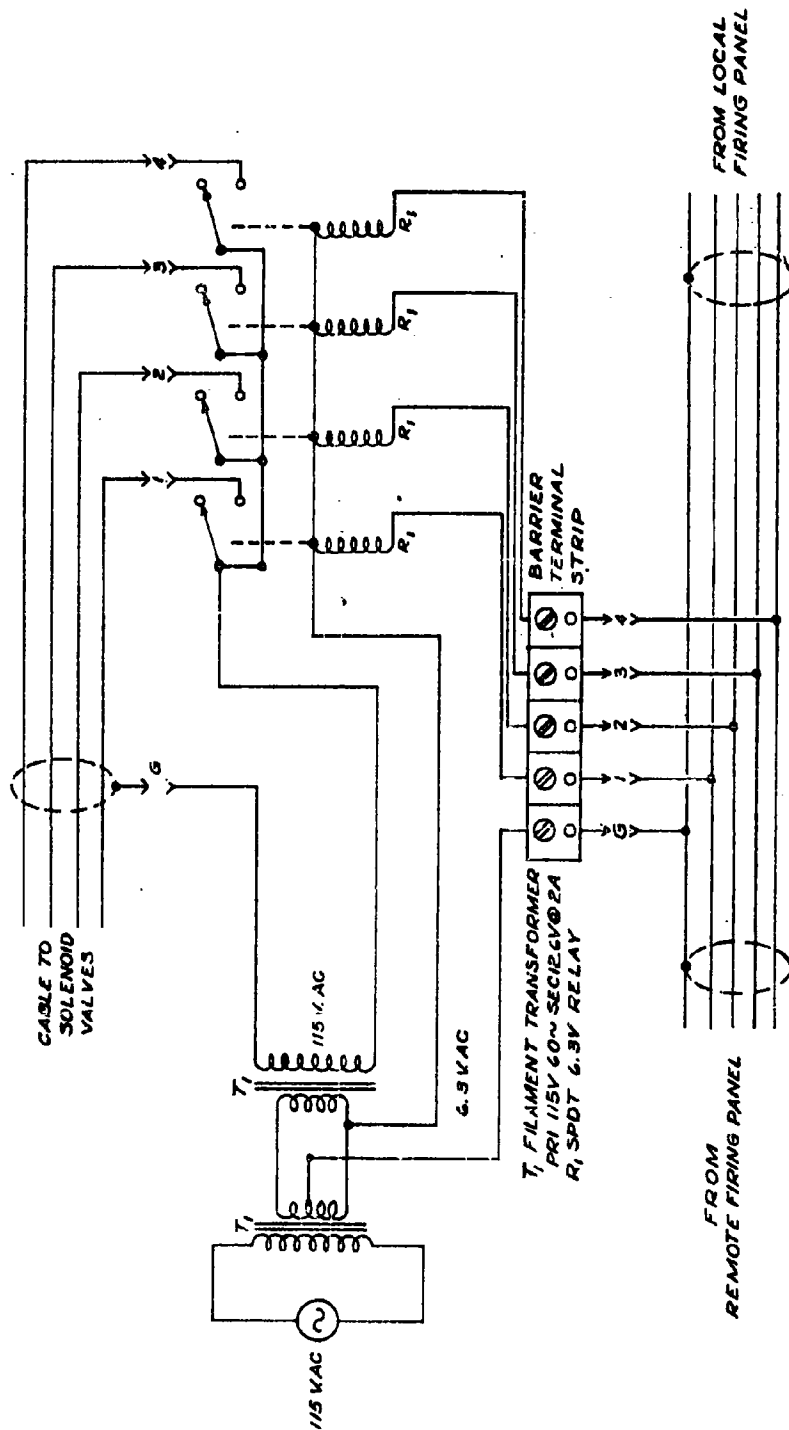


Figure 7. Bottle controls.

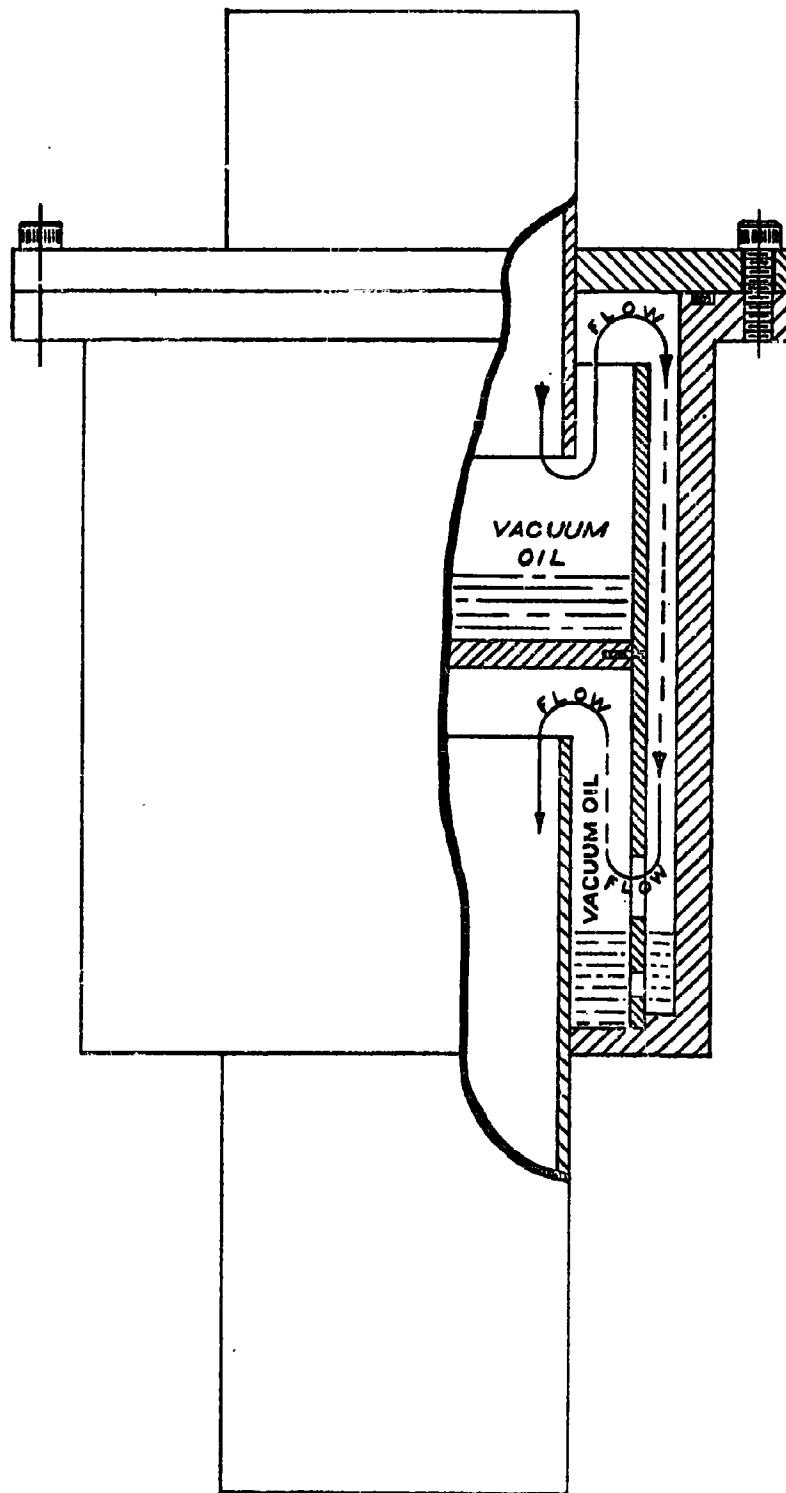


Figure 8. Oil trap.

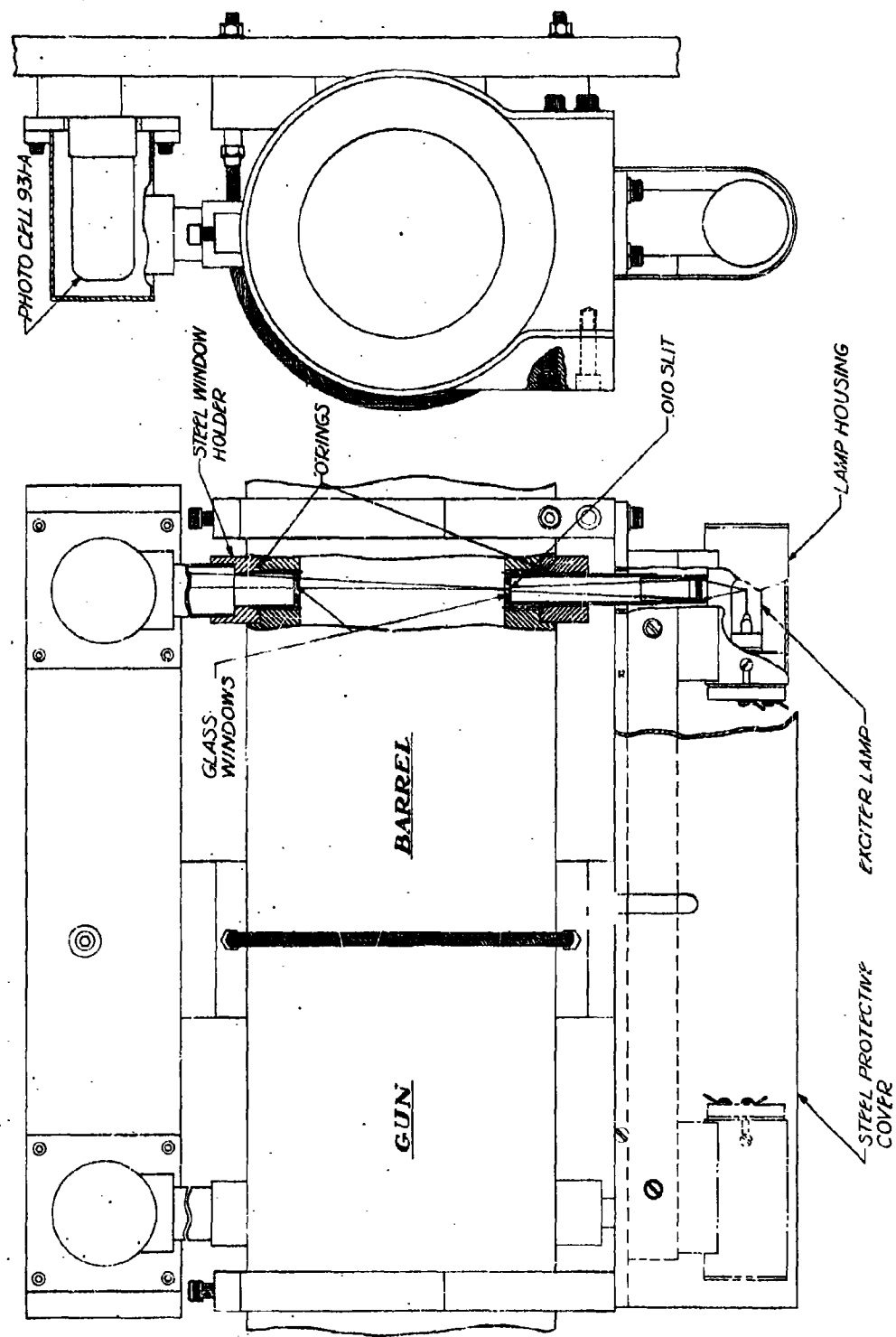


Figure 9. Photocells showing top and end.

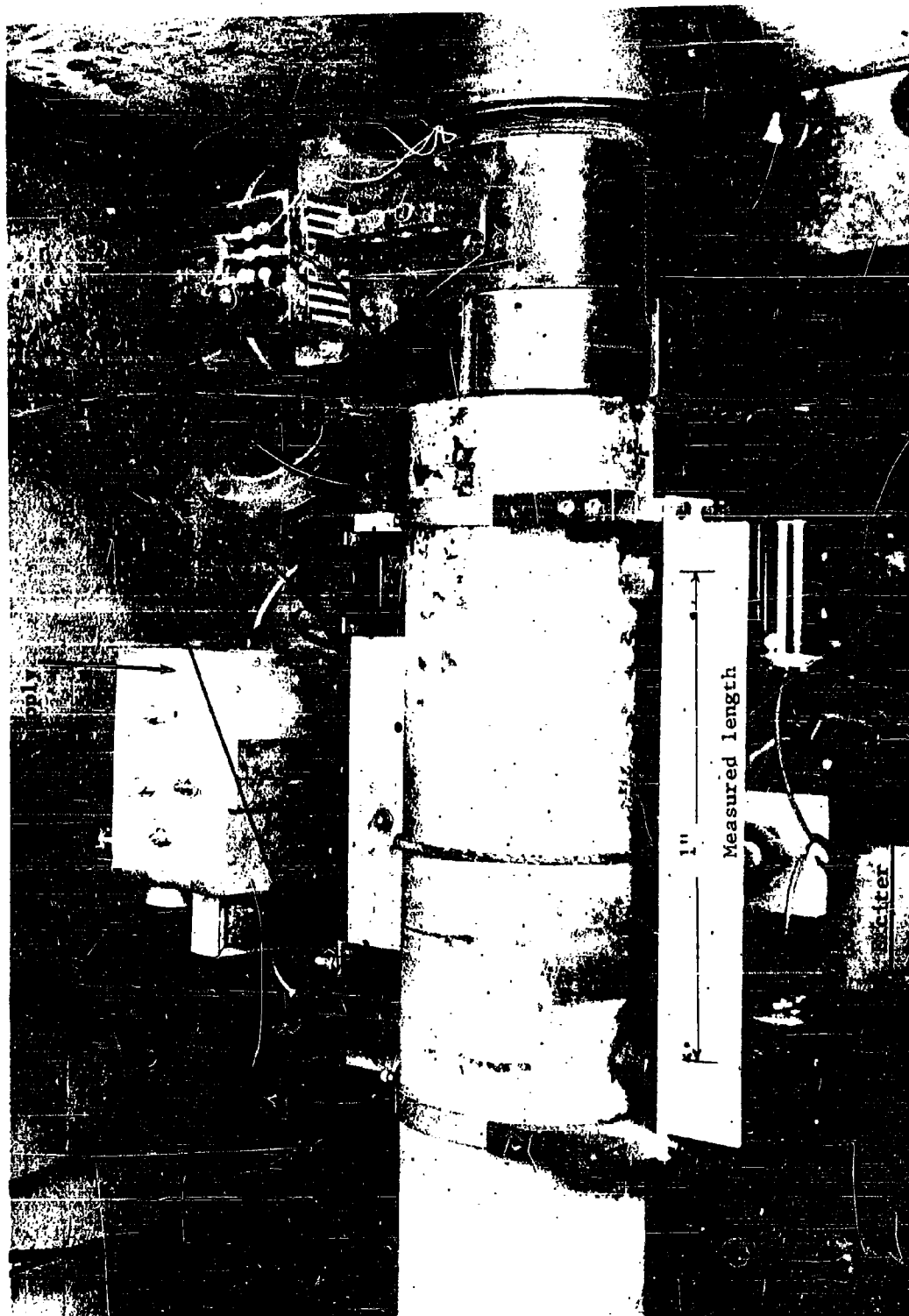
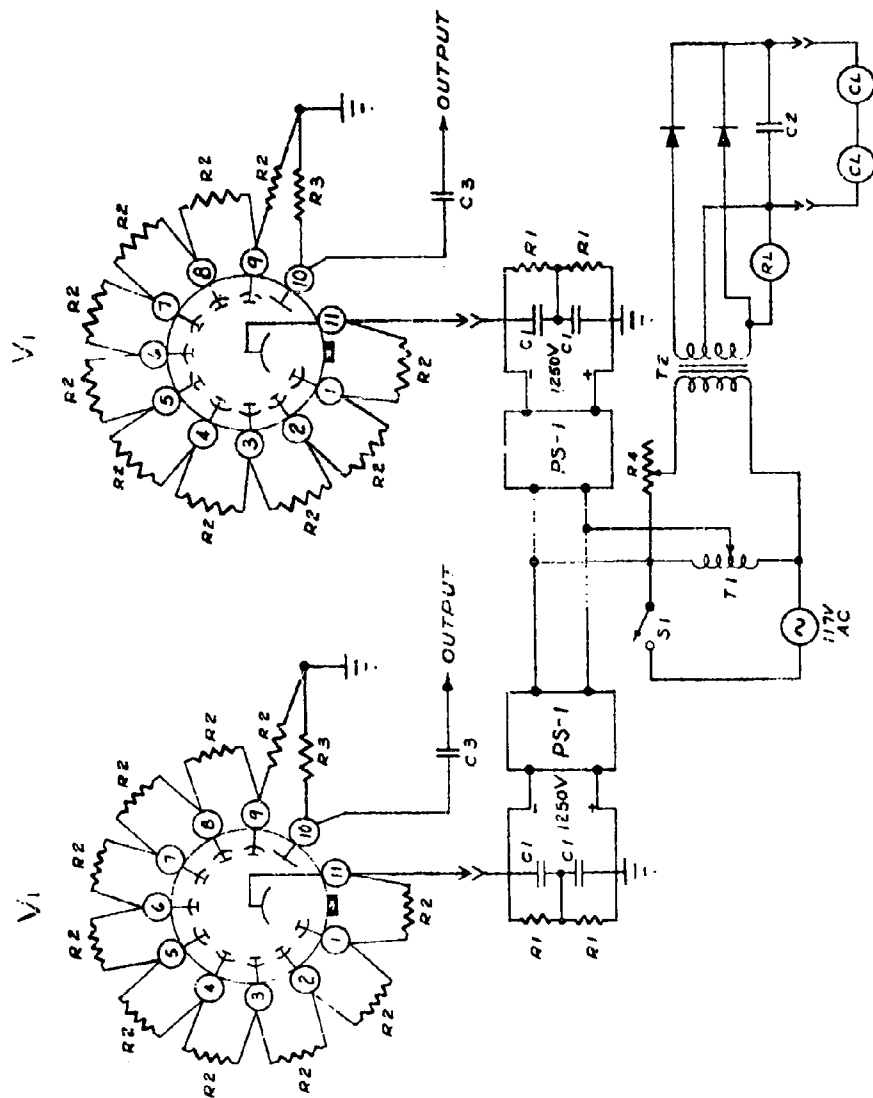


Figure 10. Photocells mounted on gun. 3361-60



$V_1 = 931A$
 $R_1 = 51 MEG \Omega$
 $R_2 = 4.7 K \Omega$
 $R_3 = 5.1 K \Omega$
 $R_4 = 100 \Omega 10W$
 $C_1 = 1.0 MFD 600WV$
 $C_2 = 4000 MFD 12 WV$
 $C_3 = .02 MFD 600WV$
 $T_1 = STANDARD ELECTRIC$
 PRODUCTS CO.
 VARIABLE TRANSFORMER
 TYPE 100 BU
 $T_2 = STANCOR PB130$
 $P 117V 60 \sim$
 $S12.6V 2A$
 $PS_1 = FCI 110VOLT$
 POWER SUPPLY
 MOD. PS 2-S
 INPUT 117V AC 60W
 OUTPUT 2KV DC
 AT 5.0 MA

Figure 11. Photo multiplier circuit.

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